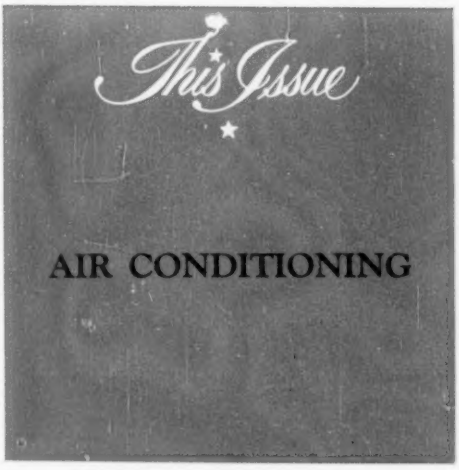
Volume 47 JULY, 1961 Number 7

Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants



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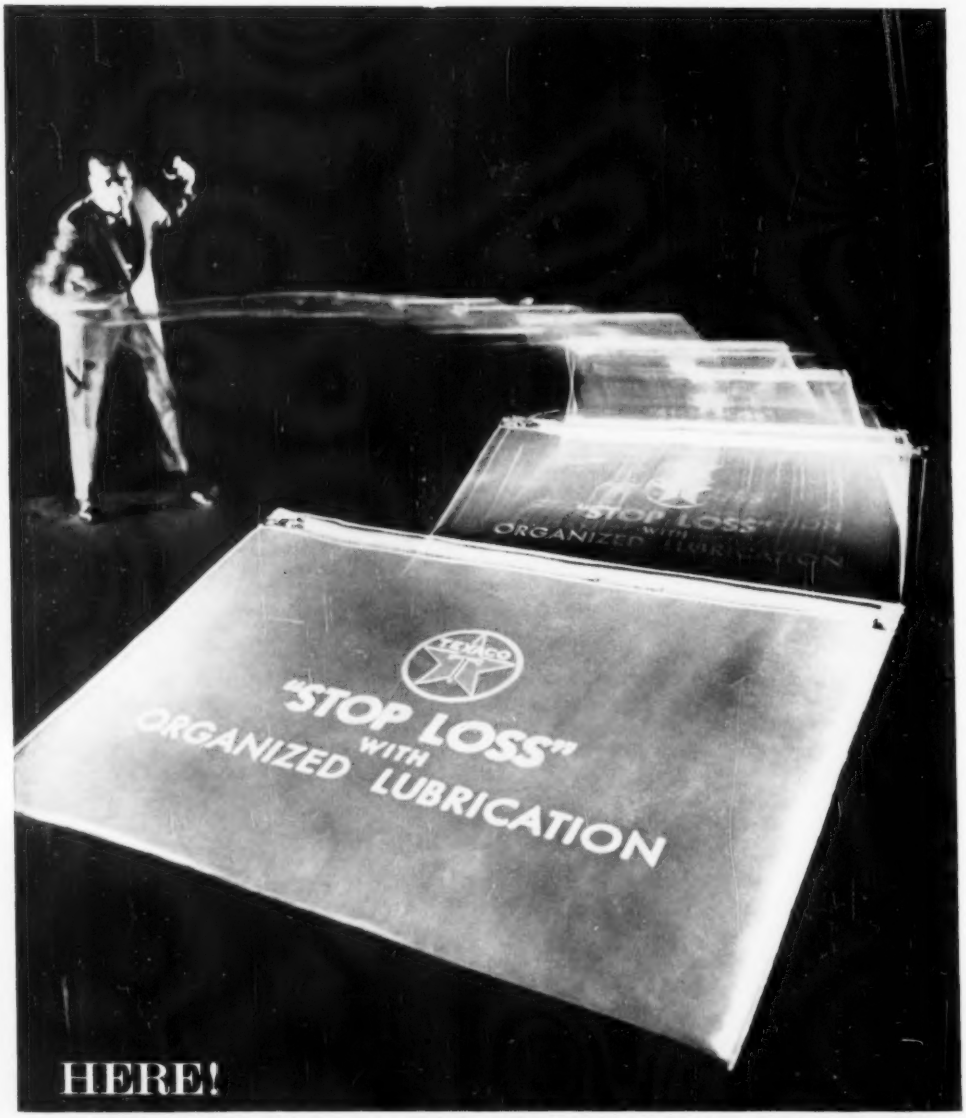

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LUBRICATION

A TECHNICAL PUBLICATION DEVOTED TO THE SELECTION AND USE OF LUBRICANTS

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AIR CONDITIONING

SINCE the beginning of time, man has sought to provide himself with comfortable surroundings. Thus, in the distant past, entire tribes migrated vast distances to escape the extremes of winter's cold and summer's heat. At an early date, man learned to obtain warmth from primitive fires. However, cooling his environment required waiting until less than 100 years ago for the necessary technology. In the 1870's, Linde, Pictet and others devised refrigerant compressors which furnished the basis for development of today's refrigeration equipment used in cooling and otherwise controlling the condition of air in modern man's indoor living and working areas.

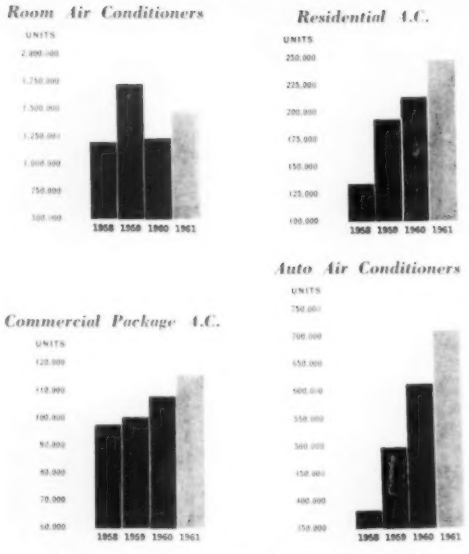
The term "air conditioning" is commonly used to refer only to cooling of air. However, air conditioning is properly defined as the simultaneous control of temperature, humidity, air flow and air purity in a given enclosure. Such control of environment contributes daily to the comfort and health of millions of people. Moreover, the use of air conditioning in industry has facilitated the manufacture of a large variety of products. These vital applications are served by a vast air conditioning industry employing thousands of people in the development, manufacture, distribution, operation and maintenance of equipment. The growth of air conditioning in the past few years is illustrated in Figure 1.

Air conditioning can be divided into the two main subdivisions inferred above: comfort and industrial air conditioning. Comfort air conditioning gives rise to the terms "summer air conditioning," "winter air conditioning" and "complete air conditioning." As would be deduced from these designations, summer air conditioning includes cooling but not heating of air, winter air conditioning heating but not cooling and complete air conditioning includes either heating and/or cooling as required with probable additional control of air humidity, ventilation, distribution and purity. The design, operation and lubrication of various types of air conditioning equipment are outlined briefly below.

TEMPERATURE CONTROL

Since temperature is controlled in all except the most rudimentary systems, the air conditioning unit usually will contain either a heating unit or a cooling unit. The heating unit normally consists of an enclosed space in which to burn a fuel and a means to transfer the heat evolved to the air which it is desired to heat. The heat transfer may occur directly, as in a furnace, or through a secondary fluid medium such as water or steam which may be employed to transfer heat from the immediate vicinity of its evolution to a remote location. This latter procedure is sometimes more practical and economical than circulating the entire mass of air past the vicinity of the heat evolution.

The number of moving parts in the heating unit



Courtesy of Air Conditioning, Heating & Refrigeration News

Figure 1—Growth of air conditioning.

which require lubrication is rather small. Certain types of burners have revolving parts requiring lubrication of their bearings at certain intervals. Other equipment requiring lubrication includes pumps for fuel or for transfering a secondary fluid medium, circulating or ventilating fans, shutters and electric motors powering the various components. None of these applications is usually very severe; therefore, general purpose lubricants normally will suffice.

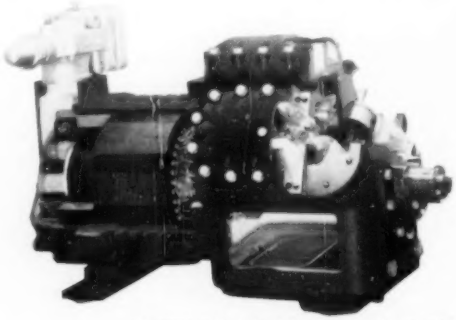
The cooling unit essentially consists of a compressor, condenser, evaporator, refrigerant, tubing and controls. The compressor acts to raise the pressure of refrigerant gas, simultaneously raising its temperature. The condenser is externally cooled by air or water and acts to cool and liquefy the hot compressed refrigerant gas from the compressor. The cool liquid refrigerant is passed through a pressure reducing or expansion device to the evaporator where it evaporates to a gas. This process requires heat which is picked up from the air or other fluid medium that surrounds the evaporator. This air or fluid medium is, of course, the material which it is desired to refrigerate: either air for use directly in air conditioning or a fluid medium, such as water, which may be pumped to a remote location to cool air in an additional heat exchanger. To complete the refrigeration cycle, low pressure, warm refrigerant gas is picked up from the evaporator by the compressor suction, compressed as before, and reused in the condenser and evaporator on new successive cycles.

OPERATION OF COMPRESSORS

The compressor functions somewhat as a pump, being designed to transfer the refrigerant gas from a vessel at comparatively low pressure to one at higher pressure. It is a precisely built machine having a number of internal parts and possibly some external parts that require lubrication. The compressor power source may be an electric motor, steam engine, steam turbine or internal combustion engine. The compressor places a rather severe duty on lubricants because of close fits, temperatures caused by compression and expansion, and the presence of various metals, refrigerants, and often electrical components, in contact with the oil. Specialized characteristics are required to meet this duty, and these characteristics are supplied by preparing special lubricating oils for refrigeration and air conditioning compressor service.

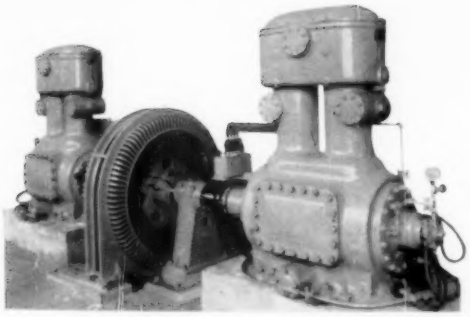
Reciprocating Compressors

The reciprocating compressor is not unlike the automotive engine in principle or design. Depending on requirements, cylinders may number from one to as many as sixteen in a single machine. Cylinder arrangement can be varied as needed by the designer and include horizontal, vertical, "V," "W" or radial arrangements. Pistons are fitted into the cylinders with suitable connecting rods, wrist pins and crankshafts. Various reciprocating compressor configurations are shown in Figures 2, 3, 4, 8 and 9. Although compression and oil scraper piston rings are generally used in large compressors, piston rings are not used on many of the fractional and one to three horsepower units. In the latter case, very close fits between the pistons and cylinder walls are provided and the lubricating oil film provides the necessary seal. Although the gas charge may be taken into the top of the cylinder as is customary in the four-stroke cycle automotive engine, the reciprocating refrigerant compressor may draw low pressure gaseous refrigerant from the crankcase, using cylin-



Courtesy of Copeland Refrigeration Corporation

Figure 2—30 Hp., 6 cylinder, accessible hermetic motor-compressor.



Courtesy of Frick Company

Figure 3—Dual-connected two-cylinder 10" x 10" ammonia compressors.

der ports as in a two-stroke engine, or valve mechanisms integral with the piston.

Rotary Compressors

The rotary positive displacement type compressor brings about compression through the rotation of an eccentrically driven roller moving in a gyratory manner in a closed cylinder. Inlet and discharge passages are separated by one or more blades. These blades are held in contact with the roller by springs at start up. Discharge gas pressure supplies most of the force to the vane after operating pressures are reached. One type of rotary compressor is shown in Figure 5.

Centrifugal Compressors

In design and construction, centrifugal compressors are similar to centrifugal pumps. A rapidly rotating impeller rotates low pressure gas and discharges it outwardly by centrifugal force, thereby increasing pressure. By successively passing the gas through additional impellers or stages, higher discharge pressures are realized. The centrifugal compressor is a constant pressure machine capable of handling a high volume of refrigerant at high, even pressures. With no rubbing parts such as piston rings and cylinder walls, wear is not a problem. Considering that the motion is purely rotational, the absence of vibration in this machine is not unexpected. The centrifugal compressor is particularly well suited to heavy duty, continuous, large horsepower operations. Figures 6 and 7 illustrate compressors of this type.

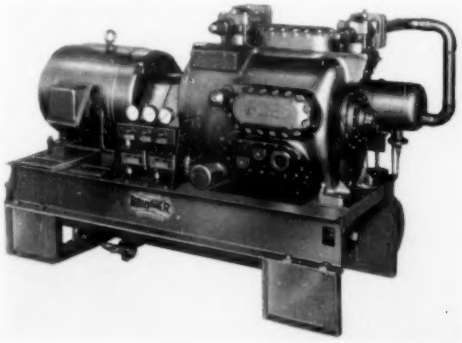
Hermetic Units

While original designs for refrigeration equipment generally comprised separately assembled, open-type compressors, belt or shaft driven by a separate motor, the recent trend in "small" compressor sizes below 5 HP motor capacity, and occasionally in the intermediate or 7.5 to 10 HP range, has been toward the sealed or hermetic unit. Hermetic units of various types are shown in Figures 2, 5, 6, 8 and 9. In these, the electric motor is built into the same casing as the compressor; the electric motor driving section and the refrigerant compressing section, whether reciprocating or rotary type, are mounted at opposite ends of a single shaft. Both sections are exposed to the refrigerant vapors and heat of compression and are lubricated from the same oil reservoir.

Hermetic units are usually factory-assembled and sealed and extreme precautions are taken to exclude all foreign materials such as moisture, air and dirt. The units may be of the "sealed" type with the parts of the case brazed or welded together, or of the "accessible" type with through-bolted, flanged or possibly gasketed components. The sealed type units are ordinarily returned to factory service departments for any repairs necessary; the accessible type can undergo certain repairs or replacement of parts in the field, providing all due precautions are taken to exclude air, moisture, etc., as in the original construction of the unit.

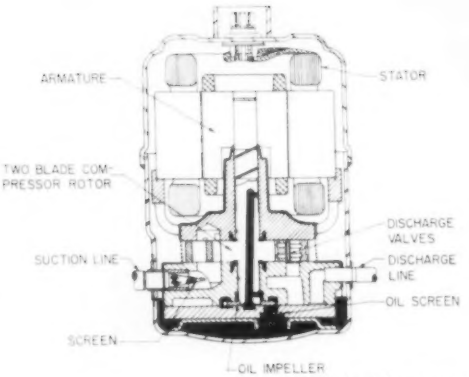
APPLICATIONS AND EQUIPMENT

Figures 10 through 16 illustrate seven different room-type air conditioners which have become very popular due to their relatively simple installation and reasonable cost. The continued popularity of these units is forecast in Figure 1. Another growing application of air conditioning is in automobiles, one installation being shown in Figure 17. The heat pump, Figure 18, is an air conditioning device of considerable interest for transferring heat into or out of a building to maintain the desired indoor temperature; in some applications, the heat is transferred to and from an underground water source of essentially constant temperature. Other applications may employ absorption or steam jet refrigeration systems. In any event, air conditioning provides such useful benefits that new applications are being developed continuously. The equipment used varies considerably in design as required to handle the con-



Courtesy of Dunham-Bush Inc.

Figure 4—Direct-drive reciprocating compressor with condensor.



Courtesy of Whirlpool Corporation

Figure 5—Vane-type rotary compressor and motor, hermetically sealed and permanently lubricated.

ditioning of air in the most efficient and economic manner for the specific application.

AUXILIARY EQUIPMENT

As in a heating plant, an air conditioning cooling unit may include pumps for transferring a secondary fluid medium, circulating or ventilating fans, shutters and external electric motors, all of which require oiling or greasing with general purpose lubricants in accordance with their manufacturers' recommendations. Some large units may be powered by steam pumps or turbines which require the proper grade of steam cylinder or turbine oil. Features of the auxiliary equipment which may be utilized to control humidity, circulation, ventilation and air purity in the overall comfort air conditioner are described below.

Purification

Purification of air is another prime function of air conditioning. The movement of air in an enclosed area past a given point provides an excellent opportunity to remove dust, fumes, pollen, odors and other contaminants. Air cleaning devices are generally classified as follows:

Centrifugal collectors
Air washers
Dry type filters
Viscous filters for manual operations
Viscous filters for automatic operations
Electrostatic precipitators
Adsorption equipment

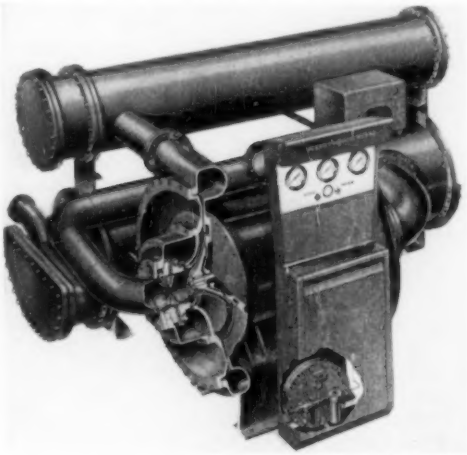
These devices are installed in the duct system, preferably ahead of the coils or at the intake of unit air conditioners. The air cleaner must be of sufficient size to permit most efficient unit operation. Periodic inspection is necessary to prevent reductions in air flow resulting from plugging. Automatic alarm devices are installed in many units to indicate when servicing is in order.

The particular type cleaner to be used is governed by the nature of the material to be removed from the air. Some will remove heavy particles and pass fine particles, others will remove fine particles but become plugged if subjected to heavy particles and still others will remove fumes, organic vapors or odors but will be ineffective with regard to solids. Quite frequently a combination of cleaners will be used.

Provision must be made for removal of filters to permit cleaning, replacement or reactivation. The filter media may be treated with a viscous liquid to increase efficiency and special petroleum base filter coating materials are often used for this purpose. Filters are frequently mounted on an endless chain, passed through the air stream, then through a cleaning bath following which they are recoated, drained and allowed to cool before re-entering the air stream. Upon cooling, the coating congeals, eliminating messy drippage from the filter upon returning to service.

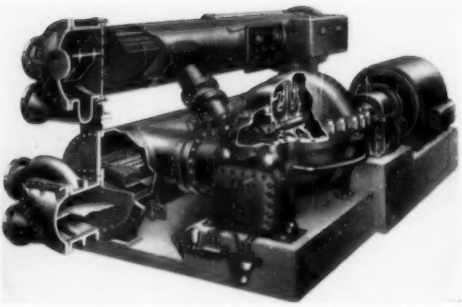
Humidity Control

Room, residence and other small "comfort" air conditioning installations merely remove a portion of the moisture present in the air when on the cooling cycle or evaporate water from an open reservoir into the air when on the heating cycle. This tends to result in a variable humidity having a numerical value that is a function of the temperature of the air inside the air conditioning unit, the proportion of total air circulated and the temperature the conditioned air assumes upon return to the enclosed space. Close control of humidity is generally required on larger, industrial units and a reasonable range of selected humidities can be provided by the use of suitable controls. On the cooling cycle, a thermostat and a humidistat are used to control tem-



Courtesy of Worthington Corporation

Figure 6—Hermetic centrifugal compressor system.



Courtesy of Carrier Air Conditioning Company

Figure 7—Open-type 2 stage, centrifugal compressor.

perature and humidity in one such system. During periods of acceptable humidity, the thermostat operates to modulate the flow of cooling water to a coil over which the circulating air passes. As humidity increases, the humidistat overrides the modulation feature of the thermostat, causing the control valve to work only in a two-position, "on-off" manner. Although the thermostat can prevent the temperature from falling too low in the enclosed area, maximum cooling and dehumidification occurs during the cooling period. Methods of introducing temperature and humidity-controlled air have been devised to cover a variety of other combinations of cooling, circulating and ventilating for humidity control.

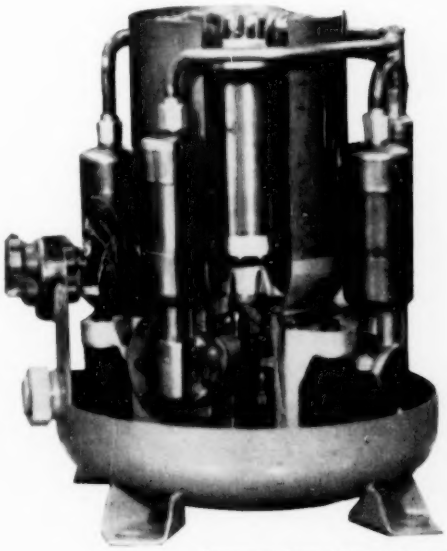
Newer houses or stores which are more tightly constructed may not permit accidental air leakage for ventilation and may become overly moist during the winter or in their cool, dark cellars in summer. Mechanical dehumidifiers, comprising a complete small refrigeration unit, may be set up in such spaces. The cold evaporator is used to condense water from the circulated air, delivering the condensate to a drain. The condenser is air cooled and acts to heat the air in the space. Both actions tend to dry the air and eliminate undesirable condensation on cool surfaces or the prevalence of mildew in storage spaces.

Circulation and Ventilation

It is not practical to move all of the air in an enclosed space past the heat transfer surface in a short period of time so that the temperature of the air returning from the heat transfer area is at the temperature desired in the enclosed space. Therefore, only a portion of the air is circulated. This air is over-heated or under-cooled and over or under-humidified so that subsequent mixing with the bulk air will result in the temperature-humidity control desired. It is apparent that proper air distribution is of extreme importance. Also, drafts or excessive noise will transform an otherwise properly designed system into an uncomfortable, undesirable installation.

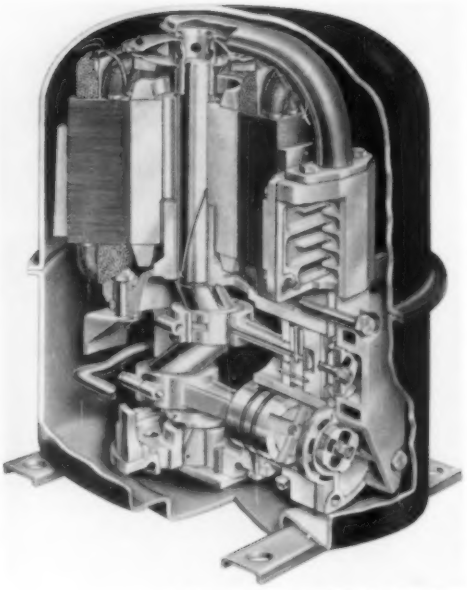
No attempt will be made to cover the broad scope of proper air distribution in this article. The various principles and application of air distribution are covered in many text and reference books. Additionally, new developments are covered in trade literature. However, it may be stated that small air conditioning units generally have integral fans and grill work designed to discharge the conditioned air with a maximum space coverage and a minimum of direct draft. Larger systems use duct work designed for the space, considering not only the load imparted by climatic conditions but also by occupants.

Aside from the above features of circulation, the air conditioning system must usually provide for ventilation of the enclosed space, i.e., exhaust of stale air, which may contain odors, fumes and smoke, and the introduction of fresh air to replace the stale. The general principles utilized include maintaining a small positive pressure on the conditioned space, sizing intake fans and duct work to introduce up to 100% outside air when conditions make it economically feasible, and conditioning the fresh intake air as it is introduced. Many other features must be considered as the design of a particular installation progresses. General limits for proportion of air circulated and air velocity under various circumstances have been established, and of course the cost and appearance factors must be considered.



Courtesy of General Electric Company

Figure 8—4 cylinder, hermetic motor-compressor (with upper portion of case removed).



Courtesy of Tecumseh Products Company

Figure 9—2 cylinder hermetic motor-compressor.

LUBRICATION PRACTICES

Air conditioning compressors are lubricated by splash, flood and forced feed systems. Although splash and flood systems are more adapted to vertical reciprocating and rotary compressors, the forced feed system is more universally applicable. The type of lubricating system used will greatly influence the oil viscosity grade required to insure satisfactory lubrication.

In splash lubrication the oil level is carried just high enough to permit the crank to dip into it and splash sufficient oil on the cylinder walls and bearings. Oil is distributed at each revolution of the crank. A fog of oil is formed above the oil level in the crankcase which assists in lubrication of bearings, providing clearances are sufficiently large to permit the entrance of oil. However, splashing of dippers in oil and larger bearing clearances may result in an unacceptedly high noise level. Splashing at high speeds may cause frothing and oil pumping into the refrigerant system. Although no problem in package type equipment, this could cause difficulties in remote systems with long gas lines. Proper equipment design and careful oil selection can minimize these potential problems.

Flood systems include the arrangement of discs, vanes, screws, shaft grooves, oil rings, gears or other devices which raise oil from the compressor's sump to shaft or bearing level from which it gravitates to other parts requiring lubrication. Little or no pressure is developed by these systems and they should not be considered as forced feed systems. As compared to splash systems, the oil is less violently agitated, resulting in less fogging, frothing and carryover; oil is more positively transferred and quieter operation is realized.

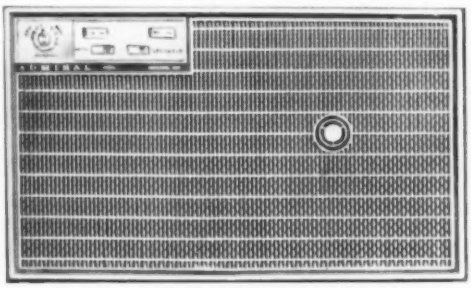
Forced feed systems develop pressure from gear, vane or piston-type pumps which force the correct amount of oil to the various parts through tubing or cast or bored passages. Utilization of such a pressurized system permits use of closer fitting parts and results in a quieter operating machine. Additionally, positive oil flow also results in better heat dissipation. Oil coolers may also be included in the lubricating oil system to increase heat removal.

Internal and external parts are lubricated individually on many types of larger machines. A mechanical forced feed lubricator with several outlets supplies lubricant to the cylinders, internal bearings and stuffing boxes and an independent gravity or pressure circulating system supplies oil to external bearings.

The forced feed system permits effective purification or filtration of the oil during circulation. A fine wire mesh screen over the pump suction on even the smallest machines is installed to remove particles of metal and miscellaneous debris, thereby preventing damage to the unit. Filters designed to remove not only metallic particles but also much smaller contaminants are often installed in larger machines. These filters may be of the full flow or by-pass type.

EFFECTS OF REFRIGERANTS ON LUBRICATING OIL

The choice of a refrigerant will be influenced by the specific conditions to be met by an air conditioning system. The refrigerant, once chosen, will influence the design of the compressor and the characteristics required in the lubricating oil. In applications where the reciprocating compressor is most advantageous, refrigerants of high vapor pressure permit lower piston displacement with consequent lower friction loss. With the centrifugal com-



Courtesy of Admiral Corporation

Figure 10—Room-type air conditioner.

REFRIGERANTS

ASRE No.[1]	Trade or Brand Names	Chemical Name	Chemical Form.	B.P.[2] °F.	Behavior in contact with Mineral Lubricating Oil	Comp. Type[3]	Oil Vis.,[4] SUS. 100°F.
717		Ammonia	NH_3	—28	Solubility fairly low. If impure, may form sludge	R	300
744		Carbon Dioxide	CO_2	—109.3	Solubility very low. Not reactive	R	300
764		Sulfur Dioxide	SO_2	14.0	Solubility low if oil highly refined. Forms gums and sludge if oil not highly refined	R	150
40		Methyl Chloride	CH_3Cl	—10.8	Soluble. Mixes to lower viscosity and Pour Point	R	150
30	Carrene No. 1	Methylene Chloride	CH_2Cl_2	105.2	Soluble. Mixes to lower viscosity and Pour Point	C	300
11	Arcton 11, Carrene No. 2, Freon-11, Frigen 11, Genetron 11, Isotron 11, Ucon 11	Trichloro-monofluoro-methane	CCl_3F	74.8	Soluble. Mixes to lower viscosity and Pour Point	C	300
12	Arcton 12, Freon-12, Frigen 12, Genetron 12, Isotron 12, Ucon 12	Dichloro-difluoro-methane	CCl_2F_2	—21.6	Soluble. Mixes to lower viscosity and Pour Point	R & C	150 300
22	Arcton 22, Freon-22, Frigen 22, Genetron 22, Isotron 22, Ucon 22	Monochloro difluoro-methane	$CHClF_2$	—41.4	Soluble at high side temperature. Dependent on temperature, type of oil and percent oil in mixture, forms two-layer system in low side	R & C	150 300
113	Arcton 113, Freon-113, Frigen 113, Genetron 113, Isotron 113, Ucon 113	Trichloro-trifluoro-ethane	$C_2Cl_3F_3$	117.6	Soluble. Mixes to lower viscosity and Pour Point	C	300
114	Arcton 114, Freon-114, Frigen 114, Isotron 114, Ucon 114	Dichloro-tetrafluoro-ethane	$CClF_2 \cdot CClF_2$	38.4	Soluble at high side temperature. Dependent on temperature, type of oil and percent oil in mixture, forms two-layer system in low side	R & C	300
114a	Genetron 114a	Dichloro-tetrafluoro-ethane	$CCl_2 \cdot F_2C$	38.5	"	"	300

[1] American Society of Refrigeration Engineers' Standard Designation Number.

[2] Boiling Point at atmospheric pressure.

[3] Compressor type: R (Reciprocating) or C (Centrifugal); in latter there is essentially no contact between the oil and refrigerant.

[4] These nominal oil viscosities are generally in agreement with manufacturers' normal recommendations. Under certain conditions and for certain units, a higher or lower viscosity may be specified so manufacturers' recommendation should always be consulted.

pressor, it is necessary that the refrigerant have low vapor pressure to reduce the number of stages. A high density of the vapor is desirable, however, to reduce compressor peripheral speed. General information on refrigerants is given in the above table.

ASRE[1] refrigerant Numbers 12, 22, 114 and 114a are the most commonly used in the hermetic units so widely favored for small air conditioning units. A special ASRE refrigerant, No. 500, is occasionally used to compensate for the capacity reduction caused by the reduction in speed occasioned when a 60 cycle motor is connected to a 50 cycle power source. Large scale air conditioning units employ a wide variety of refrigerants. However, ammonia or sulfur dioxide are most apt to be used in installations where the primary cooling system is remote from the space cooled; e.g., where water is cooled and circulated to space coolers throughout a building.

These usual refrigeraants have varying degrees of miscibility with lubricating oil, ranging from practically zero for ammonia to complete miscibility for ASRE Numbers 11, 12 and 30. ASRE Numbers 22 and 114 present a special case.They will generally be completely miscible with the lubricating oil only at

[1] American Society of Refrigeration Engineers.

Courtesy of Frigidaire Division, GMC

Figure 11—Room-type air conditioner.

temperatures above a certain "miscibility temperature," and will separate into two liquid phases when cooled below that temperature, depending on the composition of the mixture. A principal effect of refrigerant dissolved in the lubricating oil is a reduction in viscosity which may reduce the ability of the oil to do its job of lubricating the machine and sealing in the refrigerant pressure.

The design of the compressor will determine the extent to which properties of the lubricant are affected by properties of the refrigerant. The centrifugal machine presents a comparatively simple problem in that there is little contact between refrigerant and lubricating oil. The leakage of the refrigerant will not be sufficiently extensive to give any concern as to the resultant lubricating ability of an oil which has been specifically refined for this class of service. In reciprocating and rotary machines having splash or flood lubrication the refrigerant circulates through the crankcase and immediately establishes equilibrium with the oil as in the sealed hermetic compressor. Machines with forced feed lubrication will vary in the degree of contact afforded between oil and refrigerant.

Apart from mechanical and constructional conditions, the amount of chlorofluoro compound type refrigerant which will be absorbed by any mineral oil will be dependent upon the nature and viscosity of the oil, the temperature and the pressure of contact. Lower viscosity oils absorb more of such refrigerants for a given weight than do higher viscosity oils. Low temperature and high pressure favor absorption. A paraffinic oil absorbs slightly less of these refrigerants than a naphthenic oil of equal viscosity.

Figure 19 indicates the magnitude of the effect on viscosity of refrigerant ("Freon-22") in solution in three naphthene and one paraffin base refrigeration-grade lubricating oils at 100°F. Data curves of this type may be used in estimating the viscosity of mixtures in the crankcase of a reciprocating or rotary compressor whose design affords intimate contact of the circulating refrigerant and the lubricating oil. The positions of the various curves will, of course, be different for different refrigerants, oils and temperatures.

OIL CARRYOVER

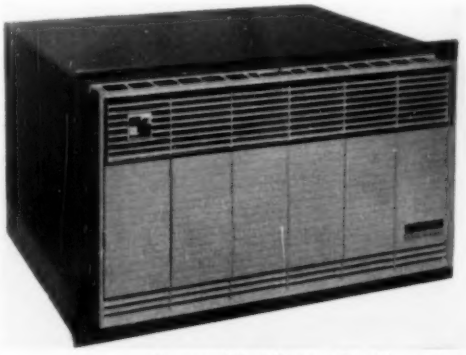
Excessive quantities of oil may be splashed on cylinder walls as a result of too violent oil agitation or too high crankcase oil level. This oil may then work past the piston rings and enter the compressed refrigerant areas where it acts as an insulator and reduces condenser and evaporator efficiencies. In some compressors oil may also be picked up by the refrigerant stream when the latter passes through the crankcase.

Oil separators are included in many designs to minimize oil carryover. In some of these designs, separated oil is returned to the crankcase for re-use. Exclusive of other considerations, the efficiency of the separator is dependent on the oil droplet size and on gas velocity. Therefore, the separator should be sufficiently removed from the compressor to permit adequate precipitation of the oil from the refrigerant gas and should have sufficient volume so that gas velocity is not too high. Where design necessitates placing the separator directly adjacent to the compressor, the highest viscosity oil that will provide satisfactory lubrication should be used, since this will have the lowest misting characteristics.

LUBRICATING OIL REQUIREMENTS

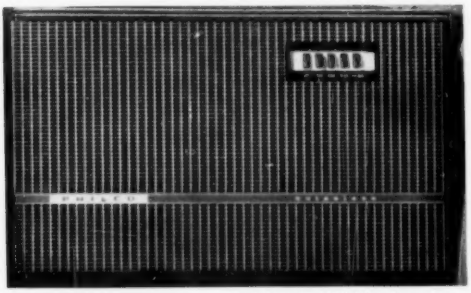
Type of Oil

The refrigeration grade oils used in air conditioning equipment are well refined "pale oils" having good stability. Until recently, these oils were generally prepared from naphthenic base crudes which are characterized by low pour points and



Courtesy of York Division, Borg-Warner Corp.

Figure 12—Room-type air conditioner.



Courtesy of Philco Corporation

Figure 13—Room-type air conditioner.

freedom from wax. These oils performed satisfactorily in many millions of units of varied design. However, the extensive use of hermetically sealed units and halogenated refrigerants resulted in the need for oils having even greater stability and lower solvent tendencies. Improvements in refining techniques have made it possible to utilize pale oils prepared from paraffinic base crudes. Both naphthenic and paraffinic base oils are used today. An even more recent addition in the lubrication area has been the introduction of inhibited refrigeration oils. The trend in the air conditioning field has been to higher speed machines with resultant increases in operating temperatures. It is expected that there will be further increases in speed and operating temperatures in future designs. These more severe operating conditions require improvements in oil stability that can only be realized by the utilization of inhibitors. The choice of a suitable lubricating oil is only made after exhaustive, long-term testing in actual equipment under normal and overload conditions. During these tests, the units are checked periodically for efficiency of operation and upon completion of testing are dismantled for complete examination of all components. Lubricating oils are evaluated by changes in their physical characteristics and by inspection of the test unit components.

Viscosity

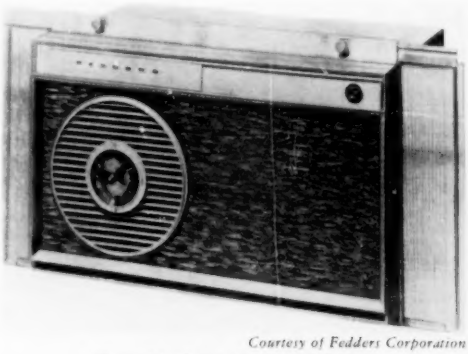
Mechanical design of the compressor, type of refrigerant used, operating temperature and type of service all govern selection of the viscosity level of the lubricating oil. In a compressor, the lubricant performs the dual function of lubricating and sealing. Generally, bearing loads are not excessive and the lubricating function is relatively easy. The sealing function is usually more difficult to accomplish and depends to a considerable extent on the pressure differences involved and the solubility of the refrigerant in the lubricating oil. Normally, the oil chosen should have the lowest viscosity that will give the required sealing properties with the refrigerant used over the range of temperatures, pressures and refrigerant dilutions expected. Most lubricant suppliers provide oils having nominal viscosities of 80, 100, 150, 200, 300 and 500 Saybolt Universal Seconds at 100°F., thus providing the design engineer a full line of lubricants.

Viscosity Index

Viscosity index (V.I.) is an arbitrary measure of change in oil viscosity with change in temperature. Oils displaying large viscosity changes with temperature changes are assigned low V.I. numbers and oils having small viscosity changes are assigned high V.I. numbers. The V.I. range of current refrigeration oils has been found to be satisfactory in assuring that when viscosity has been properly selected for normal temperatures the oil will not be too thin in a slightly overheated bearing nor too thick in a cold compressor. Although it may appear that high V.I. oils should always be used to even out viscosity differences under varied operating conditions, the higher pour test and wax content usually associated with high V.I. oils must also be considered. These latter characteristics will be discussed further below.

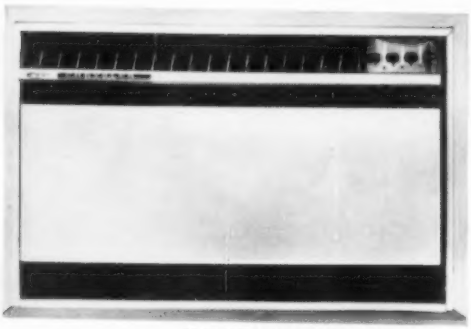
Volatility

Although compressor operating temperatures are generally well below 200°F., installations of the booster type may exceed 300°F. on the discharge side. In high temperature, high pressure applications the oil must not vaporize excessively and thus be carried over so rapidly as to overload and pass through the separator, thus giving undesirable accumulations in the cold section. Lubricant suppliers control vaporization characteristics during refining by excluding lubricating oil fractions that would be volatile at the temperatures to be encountered. This characteristic has additional significance during the dehydration step which is applied to many compressor systems with all or part of the oil charge installed. It is important that the oil should not be too volatile and thus interfere with this application of vacuum and heat.



Courtesy of Fedders Corporation

Figure 14—Room-type air conditioner.



Courtesy of Airtemp Div., Chrysler Corp.

Figure 15—Room-type air conditioner.

Foaming

Although some designers consider that a moderate amount of foaming contributes to the effectiveness of splash lubrication and muffles some of the noise of moving parts, excessive foaming generally results in excessive oil carryover past the piston and may interfere with oil pump action in a forced feed system. The degree of foaming can be controlled by the compressor designer and to some extent by the lubricant manufacturer during the refining process, or by the use of anti-foam agents of which only a few parts per million are required.

Pour and Wax

Lubricating oils are complex mixtures of numerous different hydrocarbon types. Each type has individual characteristics such as the amount of viscosity increase accompanying a reduction in temperature and the temperature at which it changes from a liquid to a solid. Thus, as any lubricating oil's temperature is progressively reduced, it becomes more viscous and eventually some of the hydrocarbons reach the temperature at which they change into the solids which are commonly called wax crystals. The formation of wax crystals contributes to further thickening of the oil. Ultimately, a temperature is reached at which all of the hydrocarbons have changed into solids. Usually before this point is reached, however, the oil has become very resistant to flow or will not flow at all.

Lubricating oils from paraffin and mixed base crudes tend to cease flow due to the interlocking network of wax crystals that form as temperature is reduced; oils from relatively wax free naphthene base crudes generally cease to flow due to the viscosity thickening action.

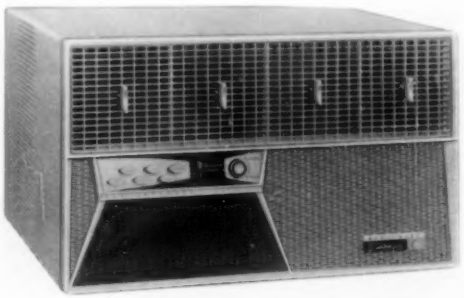
The pour test is the measure of the lowest temperature at which a petroleum oil will pour or flow when it is chilled, without disturbance, under definitely prescribed conditions. The proviso in regard to disturbance is especially important. Extensive research has indicated that any agitation or stirring of the oil while cooling causes it to solidify at a lower temperature than when held absolutely motionless. This is explained by the assumption that movement of the oil disturbs the fine wax crystal network which is forming. When undisturbed, these microscopic wax particles grow and interlock more easily into a formation that supports itself and facilitates solidification. The pour test procedure should, therefore, provide for absolutely motionless cooling during the time involved.

In the lubrication of compressors which may be exposed to low temperatures at start-up, pour characteristics can affect the initial selection of lubricating oils. These must have pour tests below the lowest expected start-up temperature to enable handling by the conventional types of oil circulating systems. The oil must also remain comparatively fluid at the lowest temperatures to which it may be subjected during the operation. These temperatures will be encountered in the expansion or refrigerating side of the system, after the refrigerant has passed the expansion valve or capillary tube. If the refrigerant is carrying a high percentage of oil at this point, any wax congealment might lead to faulty operation of the expansion device or restricted heat transfer through the coated evaporator surfaces.

Refrigerant "Floc" Test

Refrigerant dissolved in the lubricating oil will have the effect of reducing the pour point, thus widening the temperature range at which the oil may be used without difficulties from complete congealment. However, the presence of dissolved refrigerant will not necessarily completely prevent the separation of waxy components, particularly at the coldest points in the system where the proportion of refrigerant is high but the refrigerant is evaporating rapidly and increasing in concentration of oil.

A Wax Precipitation Test is, therefore, used to measure tendency to precipitate wax from the solution of oil in refrigerant. The test is usually made on



Courtesy of Westinghouse Electric Corp.

Figure 16—Room-type air conditioner.

Courtesy of Chevrolet Motor Div., GMC

Figure 17—Automobile air conditioning installation.

a 10% mixture of oil in ASRE No. 12 refrigerant, but it could be made on whatever percentage concentration and oil-soluble refrigerant the refrigeration or air conditioning system is designed to use. The temperature of the refrigerant-oil mixture is gradually reduced until a first faint wax haze is observed. This is recorded as the Wax Haze Temperature. The temperature of the mixture then is further reduced until the tiny wax crystals forming the haze gather together into observable flocs. This temperature is recorded as the Floc Point. The tiny haze-forming crystals are not considered harmful, and it is not until the crystals begin to flocculate into clumps that undesirable waxy deposits and clogging can occur in the refrigerant system. This flocing feature is probably of less importance in air-conditioning installations than in low temperature refrigeration systems, but the design of the individual installation will indicate the degree of consideration which must be given to the pour and floc characteristics of the compressor lubricating oil.

It should be pointed out that the amount of oil circulated with the refrigerant in a well designed and operating air conditioning system will usually not exceed 1 or 2% of the refrigerant circulated. An oil circulation as high as 10% should be exceedingly rare. Running the Wax Precipitation Test on a 10% mixture of oil in refrigerant thus provides a good margin of safety for translating test results to the anticipated operation of the unit.

Moisture and Dielectric Strength

Moisture in refrigeration and air conditioning systems cannot be tolerated. Moisture produces freeze-ups at the point of expansion, causing malfunctioning of the expansion control device, plugging of lines or reduced efficiency in the cooling coils. It is extremely important that all materials entering into the system and the system itself have a very low moisture content. The system is a complex mixture of many component materials that can enter into chemical reactions under the conditions of intimate contact and temperature. The presence of moisture in the system will promote and accelerate these reactions causing corrosive damage

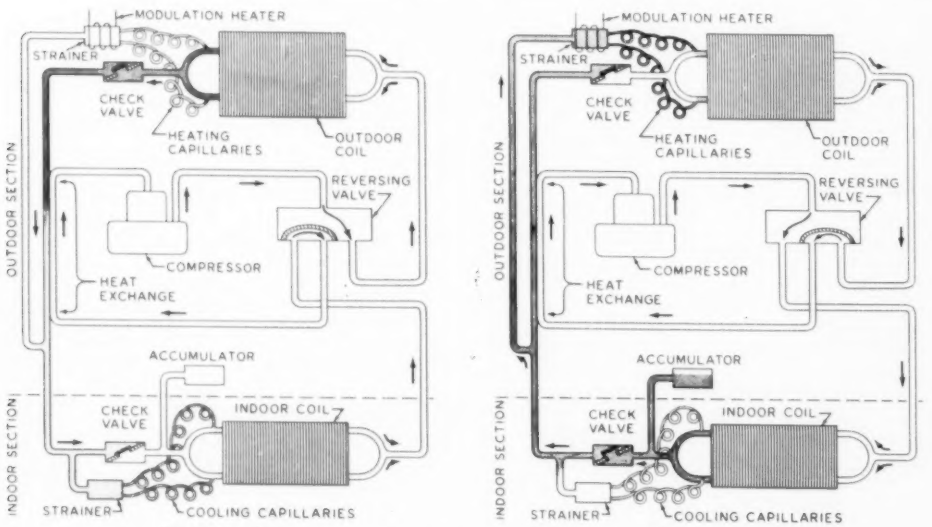


Figure 18—Operating Principle of a Heat Pump.

Courtesy of York Division, Borg-Warner Corporation

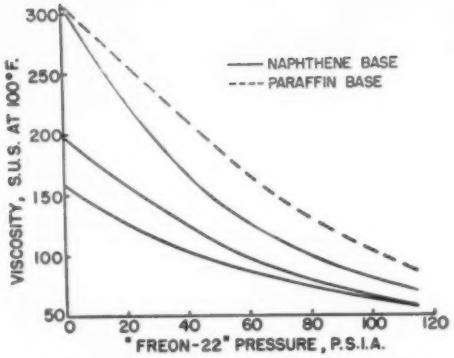


Figure 19—Viscosity of oil in equilibrium solution with Freon-22 refrigerant at a temperature of 100°F.

which may render any number of parts inoperative.

As mentioned earlier, it is common practice to dehydrate the equipment before placing it in operation. Dehydration is accomplished by the application of heat and/or vacuum, or by flushing with dry refrigerant gas. To insure that moisture is not incorporated with the lubricating oil, lubricant manufacturers employ techniques to maintain moisture content at very low levels. Oils and refrigerants are commonly supplied having moisture contents below 20 parts per million and 5 parts per million, respectively.

The Dielectric Strength Test, which is based on the resistance offered to the passage of electric current through oil, is conducted on refrigeration grade oils to assure that they are satisfactorily free of entrained moisture. The test procedure involves subjecting the oil to high voltage in a standardized cup fitted with fixed-gap electrodes of copper and brass. Resistance to a stress of 25,000 volts per millimeter of gap has been found to indicate that oils are sufficiently dry for refrigeration service. Additionally, maintenance of the 25,000 volt potential indicates the absence of solid impurities which would also be objectionable in the lubricant.

Stability

Refrigeration oils are expected to give years of service and, therefore, must be stable to heat and the effects of system materials. The careful selection of crude source and crude fraction, and the use of proper refining processes are necessary to impart the stability required. As mentioned previously, increased stability can also be imparted by the use of additives, but a combination of advanced refining and additives is usually the best method.

Average compressor operating temperatures have shown a steady increase over the years as a result of increased compression capacity, decreased available space and limited cooling water. These higher operating temperatures tend to lead to lubricant breakdown which may result in varnish and gum deposits. In a carefully evacuated system, oxygen is almost completely absent; therefore, varnish and gum deposits are not simply oil oxidation products. Although the mechanism is not fully known, these deposits are apparently complex reaction products of various oil and refrigerant fractions catalyzed or initiated by moisture, system metals, sealing compounds, etc. The presence of electrical equipment and/or stray electrical currents undoubtedly contributes to the formation of these reaction products in sealed hermetic units.

Most systems contain some copper and a phenomena known as "copper plating" has been encountered. A chemical reaction takes place whereby small amounts of copper are dissolved in the oil and refrigerant. Under suitable conditions, this copper plates out on other metallic surfaces, generally steel. Where tolerances are very close, the deposited copper may increase to such a thickness that binding and galling occur, resulting eventually in system failure. Although the mechanism is not clearly understood, it has been observed that copper plating difficulties are not encountered in completely dry systems. Copper plating has been noted in the presence of refrigerants alone which suggests that the refrigerant may be the dominant factor in the plating reaction. The theory has been advanced that minor amounts of moisture in the system produce a slow chemical hydrolysis of the halogenated refrigerants. Regardless of the mechanism involved, elimination of copper plating is an additional reason for providing moisture-free lubricants, refrigerants and system components.

CARE IN HANDLING LUBRICATING OILS

As supplied, refrigeration oils are essentially moisture-free. However, these oils will absorb moisture and care must be taken to minimize prolonged exposure to atmospheric moisture. Containers should only be opened when necessary and should be tightly re-sealed after use to prevent "breathing." Oil containers should be stored at room temperature at least 24 hours before use to minimize moisture condensation. When handling oil in bulk, vacuum dehydration and blotter pressing facilities should be provided to maintain dryness and cleanliness.

SUMMARY

This article has discussed the importance and benefits of comfort and industrial air conditioning in the modern world and shown how the proper design, installation, maintenance and lubrication of air conditioning equipment has contributed significantly to the growing acceptance and use of this means of controlling man's indoor environment.

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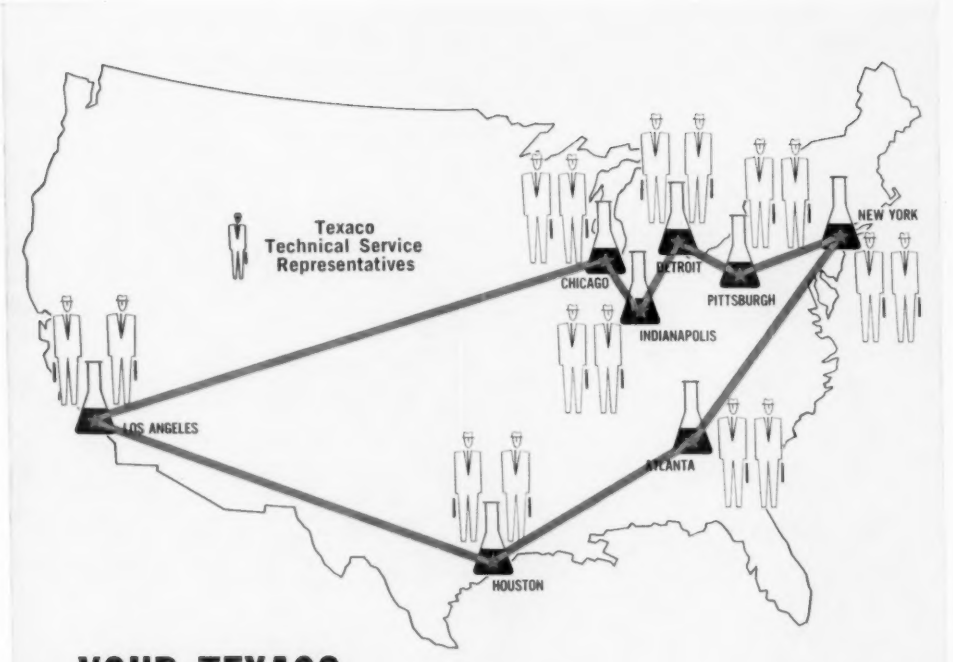

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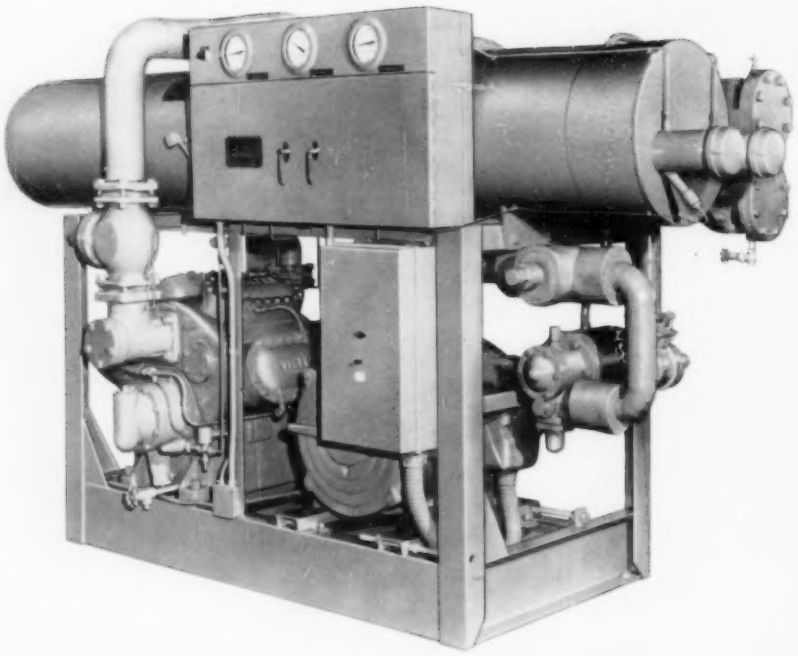

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